Hydraulic Modeling of Sugar Creek Restoration Project

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Abstract

As part of the Illinois River Basin Restoration Project, the Sugar Creek Restoration Project is being conducted to evaluate the potential to stabilize the stream and restore floodplain wetlands, reduce sediment delivery, increase connectivity of aquatic habitats, and restore degraded habitat. This Sugar Creek Project will be used as the basis for numerous future restoration projects in the Illinois River basin. From Sugar Creek's confluence with Mud Creek towards Milford, Illinois, channel instability along this two-mile reach is severe with rapidly migrating meanders, active cut-offs, toppling streamside trees, bed and bank erosion, and large logjams. An upstream-channelized reach is eroding and delivering sediment to this lower aggrading reach.

The initial phase of the study consisted of constructing a hydraulic model of the lower reach using HEC-RAS and HEC-GeoRAS and determining the effects of the logjams. HEC-RAS was used to model and compare five water surface profiles for three different geometries: with logjams, without logjams, and a channel cleared of debris. HEC-GeoRAS was used to generate water surface triangulated irregular networks of the reach. Results showed that logjams cause water depths to increase slightly for frequent events, allowing flow through cutoffs and more inundation of land. However, logjam effects diminish for larger events. To develop the project alternatives, we anticipate using this model to determine the effects of installing hydraulic structures or sediment stabilization measures in the study reach.

Introduction

The Sugar Creek Restoration Project is being conducted as part of the Iroquois River Site Specific Restoration Project, a component of the Illinois River Ecosystem Restoration Feasibility Study and Illinois River Basin Restoration. The Illinois River Ecosystem Restoration Study is authorized by Section 216 of the Flood Control Act of 1970 and Section 519 of the Water Resources Development Act of 2000.

The Iroquois River basin is located in eastern Illinois and western Indiana. The Iroquois River is the largest tributary of the Kankakee River (Figure 1). Its' watershed drains the majority of Iroquois County, Illinois and portions of Newton and Benton Counties, Indiana. Sugar Creek is one of its two tributaries. Land use changes and tributary modifications through ditching and straightening have increased velocities, bed and bank erosion, and the sediment and nutrient loads delivered to the Iroquois River and eventually the Illinois River. Channel instability results from a number of large flow obstructions (logjams) in the Iroquois River basin (Figure 2). These logjams increase bank erosion and channel re-routing and cause

localized flooding of agricultural fields. Destabilized tributary streams cumulatively contribute to the degradation of the Illinois River backwaters as increased quantities of these silty sediments are transported to and deposited in Illinois River backwaters.

Sugar Creek Restoration Project Description

The Sugar Creek Restoration Project is being conducted to evaluate the potential of stabilizing an Iroquois River tributary, thus reducing sediment delivery from the Iroquois River Basin to the Illinois River. Stream stabilization may reduce bank erosion, channel re-routing, and logjam-induced flooding thus increasing the quality of instream and riparian habitat, restoring floodplain habitat and function, and improving water quality. This project will be used as the basis for numerous future restoration projects in the Illinois River basin.

Sugar Creek originates in Indiana and flows northwesterly, entering the Iroquois River just west of Watseka. It has a watershed of 556 square miles and 38 miles of stream in Illinois. The substrate is mostly comprised of sand and gravel, with a small amount of silt and clay (Watson et al. 2002). A Rapid Watershed Assessment investigated Sugar Creek from its confluence with Mud Creek near Milford, Illinois, upstream to the Indiana state line. The lower two-miles of Sugar Creek has severe bed and bank erosion with rapidly migrating meanders, active cut-offs, toppling streamside trees, and large logjams (Figure 2). Logjams were associated with bank erosion, excessive channel widening, channel re-routing, and avulsions in (Watson et al. 2002). The channelized upstream reach is incising and eroding, delivering excessive sediment to the lower aggrading reach (Watson et al. 2002).

Possible alternatives for stream stabilization measures on the lower two-mile reach are being investigated. Grade control measures, such as riprap channel lining, concrete drop structures, and Newberry weirs, would help stabilize the study reach and prevent channel incision, bed and bank erosion and channel widening from progressing further upstream. Logjam removal would prevent channel re-routing and delivery of mobilized sediments to downstream areas while restoring connectivity of upstream and downstream aquatic habitats. Creating retention ponds or floodplain wetlands would provide habitat and may improve water quality. Bank stabilization will also be considered along the 2-mile reach to reduce sediment.

For the initial phase of the study, a hydraulic model of the lower reach was constructed to determine the effects of the logjams and their removal. In order to construct the model of Sugar Creek, a channel thalweg survey of the lower two-mile reach and a stream cross-section survey were performed in Summer 2002 (Figure 3). The bank heights, crossing locations, endpoints of the main cutoff, and the logjams are shown on the stream profile map (Figure 4). The channel profile shows a series of knickpoints or changes in slope, which correlated to five major logjam locations. In addition to stream cross-sections, a topographic survey of the main cutoff channel and a road survey were performed using a GPS (Figure 3).

Hydraulic Modeling of Sugar Creek

In order to construct a hydraulic model of the lower two-mile reach of Sugar Creek, a GIS project was first created to generate the regional geometry. Water surface profiles for three different geometries: with logjams, without logjams, and a channel cleared of debris were compared using HEC-RAS. HEC-GeoRAS was used to generate water surface triangulated irregular networks of the reach.

ArcView 3.2 model. An ArcView project was created to generate a HEC-RAS geometry file using the GeoRAS extension. Themes for the USGS quad contour maps, USGS Digital Elevation Models (DEM), cross-section survey lines and data points, cutoff channel topographic survey lines and data points were generated. The shape files were merged. Breaklines for the stream thalweg, main channel banks, roads, and some contours were added. These were used to generate a Digital Terrain Model (DTM) in the form of a triangulated irregular network (TIN) (Figure 5). The TIN was refined based on survey data and additional references such as orthophotos.

After the TIN was completed, the GeoRAS extension was loaded. The stream centerline was created. The final river network has one junction at the confluence with Mud Creek and three reaches: Sugar Creek study reach, Sugar Creek main stem and Mud Creek main stem. Themes to approximate main channel banks and the main channel, left overbank and right overbank flowpaths were created (Figure 6). A cross-sectional cut line theme was created based on survey line locations. The cut lines overlay the original survey lines but they extend out into the floodplain and doglegged. The 3D Steam Centerline and Cross Section Surface Line shapefiles were created. Finally, the geometry import file for HEC-RAS was generated.

HEC-RAS 3.1 model. A steady flow file was created. Five water surface profiles were modeled for the Sugar Creek study reach and the main stems of Mud Creek and Sugar Creek near the confluence: 05/29/02 (low flow event), 2-year, 5-year, 50-year, and 100-year recurrence interval storms. The geometry for the lower two-mile reach of Sugar Creek was imported from Geo-RAS and refined in HEC-RAS. The geometry was used to model three scenarios: with logjams, without logjams, and a clean channel. The geometry had to be slightly altered to reflect each scenario as described below. Finally a GIS export file was created and the three geometries and five profiles were import into ArcView using the Geo-RAS extension.

With logjams. This geometry reflects the current conditions of the channel including the logjams. At five surveyed cross-sections, logjams were modeled as high ground in the center of the channel that only allow flow around the sides (Figure 7). The cross-section survey was used to determine the height and widths of these logjams. Water surface profiles agree with the observed water surface elevations. Manning's roughness n-values were varied for each cross-section based on a weighted equation and ranged from 0.03 to 0.11 (Arcement and Schneider, 1990).

Without logjams. High ground was removed from the five cross-sections with logjams and cross-sections immediately upstream or downstream of the logjams if

they were influenced by the logjams (Figure 7). The streambed at the logjam locations was lowered to elevations that were between the streambed elevations of the two surrounding cross-sections. The obstruction value at all the logjam locations and surrounding cross-sections were lowered to simulate removal of the logs (n-values between 0.03 and 0.08).

Clean channel. This geometry corresponds to the entire channel being cleared of the logjams and additional snags and debris. The wetted perimeters of the cross-sections were made smoother to simulate removal of accumulated debris in the channel (Figure 8). The streambed elevation for the clean channel is the same as it was in "Without logjams". The obstruction value at all the cross-sections were lowered again to simulate removal of more debris (n-values between 0.03 and 0.07).

GeoRAS 3.1 application. The three HEC-RAS geometries files were imported back into ArcView using the GeoRAS extension. Five water surface profile TINs were generated for each geometry. Floodplain polygons and water depth grids were generated over the terrain TIN. This application allowed the water depths over the land for different profiles to be viewed.

Hydraulic model results. HEC-RAS was used to compare the five water surface profiles for three different study reach geometries (Figure 9). GeoRAS illustrated the water depth grids over the terrain TIN. These results showed that logjams cause water depths to increase slightly for frequent events, allowing flow through cutoffs and more inundated land (Figure 10). For example, the logjams raise the water surface elevation a maximum of 2.3 feet throughout the reach, and the large cutoff has flow when the logjams are present during the 05/29/02 low flow (Figure 10). However, logjam effects diminish as event frequency decreases. For a 2-year and 100-year frequency events, the logjams only raise the WSE a maximum of 0.3 feet and 0.02 feet respectively. These small differences could not be seen using GeoRAS. Therefore, logjam removal would decrease water levels of more frequent low flow events but it would not have an effect during large events. If the channel were cleared of other debris, the WSE elevations would lower even more, but those effects also small for large events.

Conclusion

The Sugar Creek Restoration Project is being conducted to evaluate the potential to stabilize the stream, restore floodplain wetlands and degraded habitat, reduce sediment delivery, and increase connectivity of aquatic habitats. This project will be used as the basis for future restoration projects in the Illinois River basin. A hydraulic model was constructed to investigate the effects of logjams and their removal. As the project develops, this model could be used to investigate other alternatives, such as installing hydraulic structures or sediment stabilization measures in the study reach. It could be expanded to include the channelized upstream reach and model its restoration efforts.

References

Arcement, G.J. Jr., and Schneider, V. R. (1990). *Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains*. U.S. Geological Survey Water Supply Paper 2339.

Watson, C. C., Roseboom, D., and Robeson, M. (2002). Watershed Assessment Methods for Illinois Streams (November 2002 Draft). Report to U.S. Army Corps of Engineers, Mississippi Valley Division.
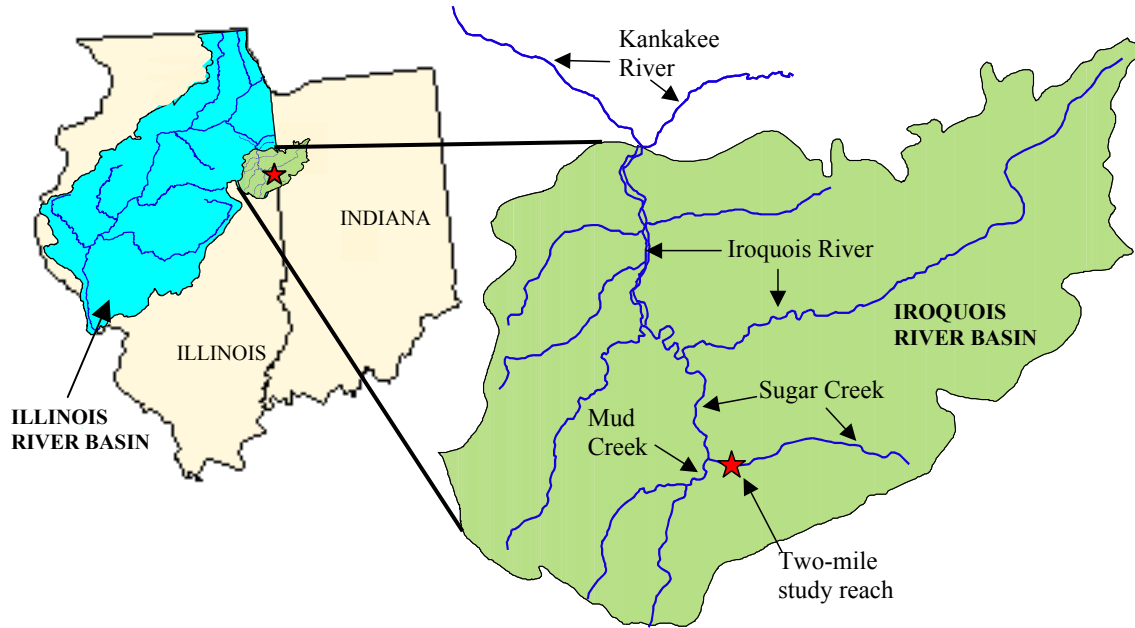
Figure 1. Location map showing the Sugar Creek Restoration project within the Iroquois River Basin.

Figure 2. Logjams along two-mile study reach of Sugar Creek, just upstream of confluence with Mud Creek. Photos taken during Rapid Watershed Assessment Aerial Mapping (Watson et al. 2003).
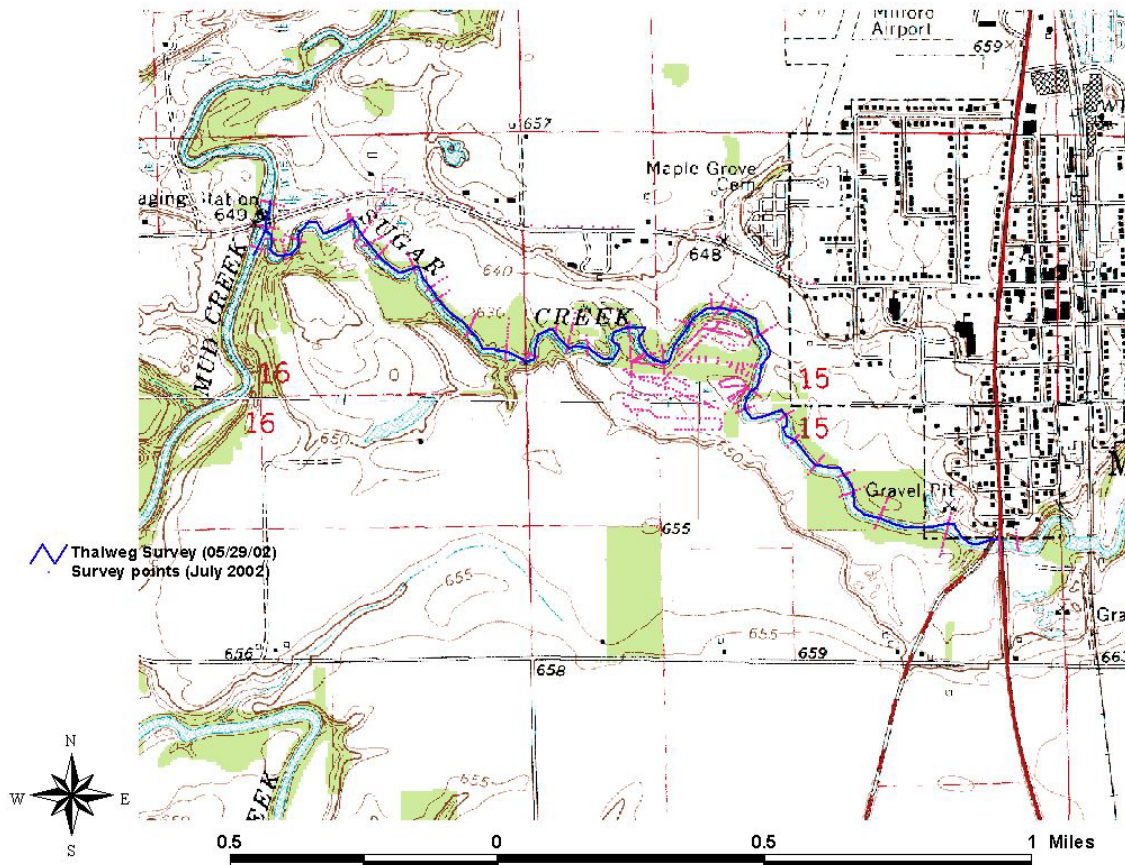
Figure 3. Sugar Creek USGS quad map showing thalweg survey line, cross-section lines and topographic survey points.
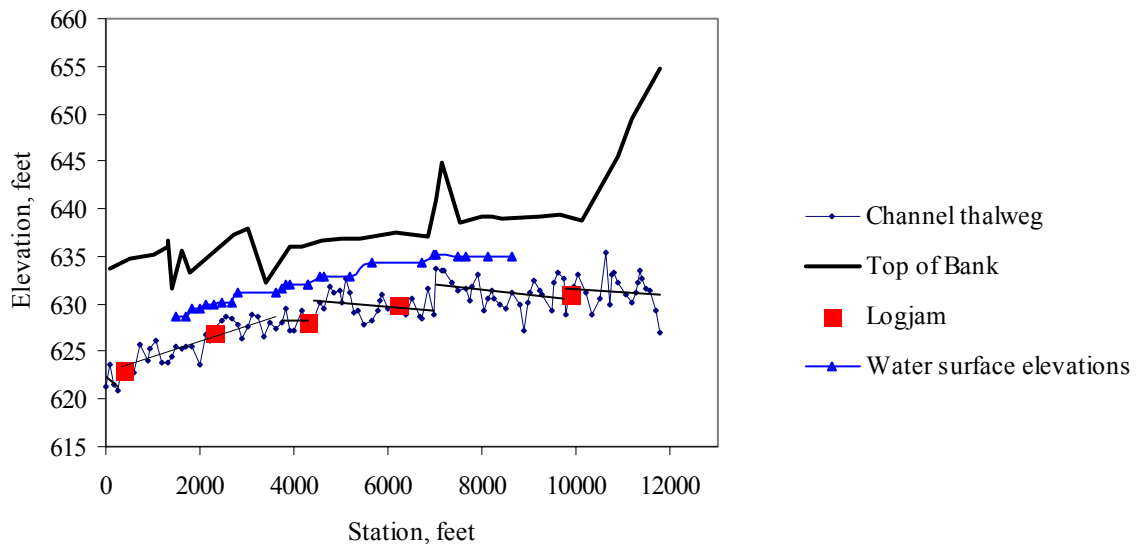

Figure 4. Sugar Creek channel survey beginning at confluence with Mud Creek and ending at Highway 1 Bridge, Summer 2002; includes thalweg profile with average channel slope for sections of the stream, top of bank, logjam locations, and water surface elevations from 05/29/02.
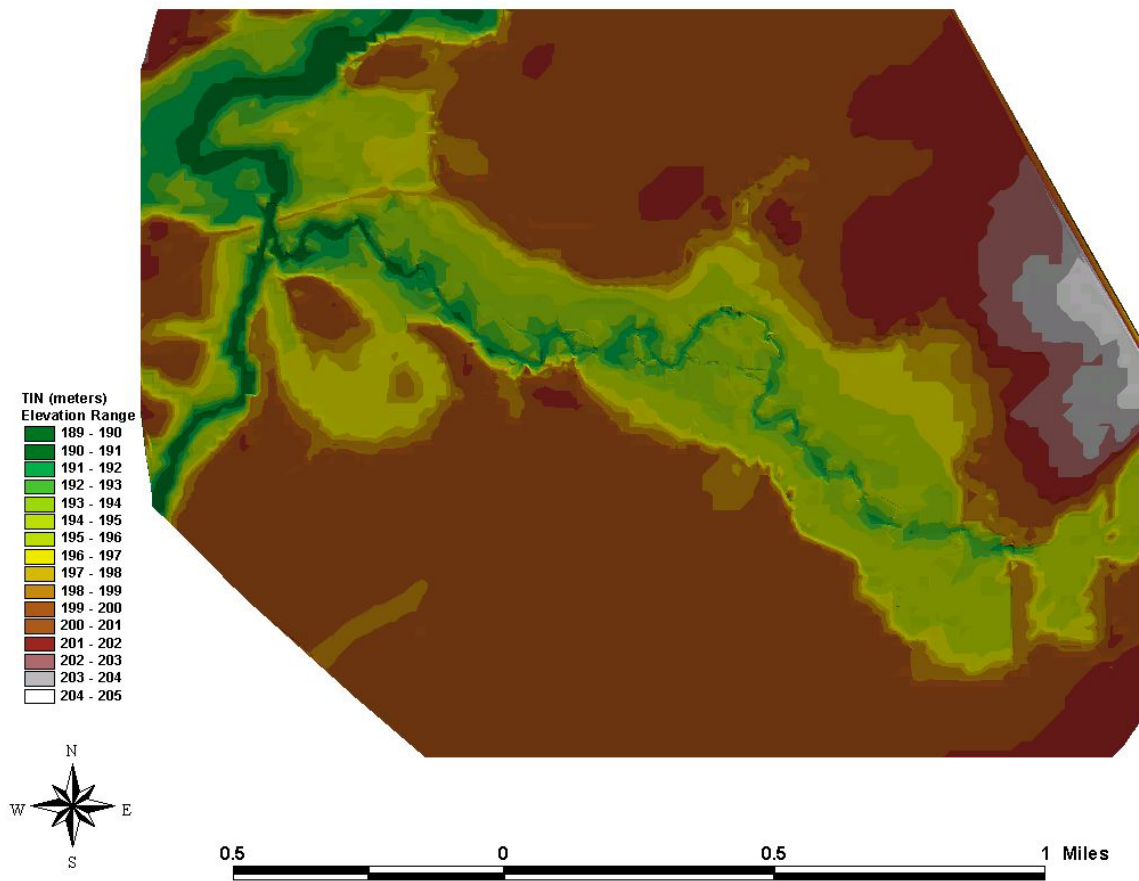
6

TIN (meters)
Elevation Range
- 189 - 190
- 190 - 191
- 191 - 192
- 192 - 193
- 193 - 194
- 194 - 195
- 195 - 196
- 196 - 197
- 197 - 198
- 198 - 199
- 199 - 200
- 200 - 201
- 201 - 202
- 202 - 203
- 203 - 204
- 204 - 205

0.5   0   0.5   1 Miles

Figure 5. Sugar Creek terrain triangulated irregular network (TIN) generated using USGS Digital Elevation Models (DEM), survey points, and breaklines for the stream thalweg, main channel banks, roads, and some contour lines.
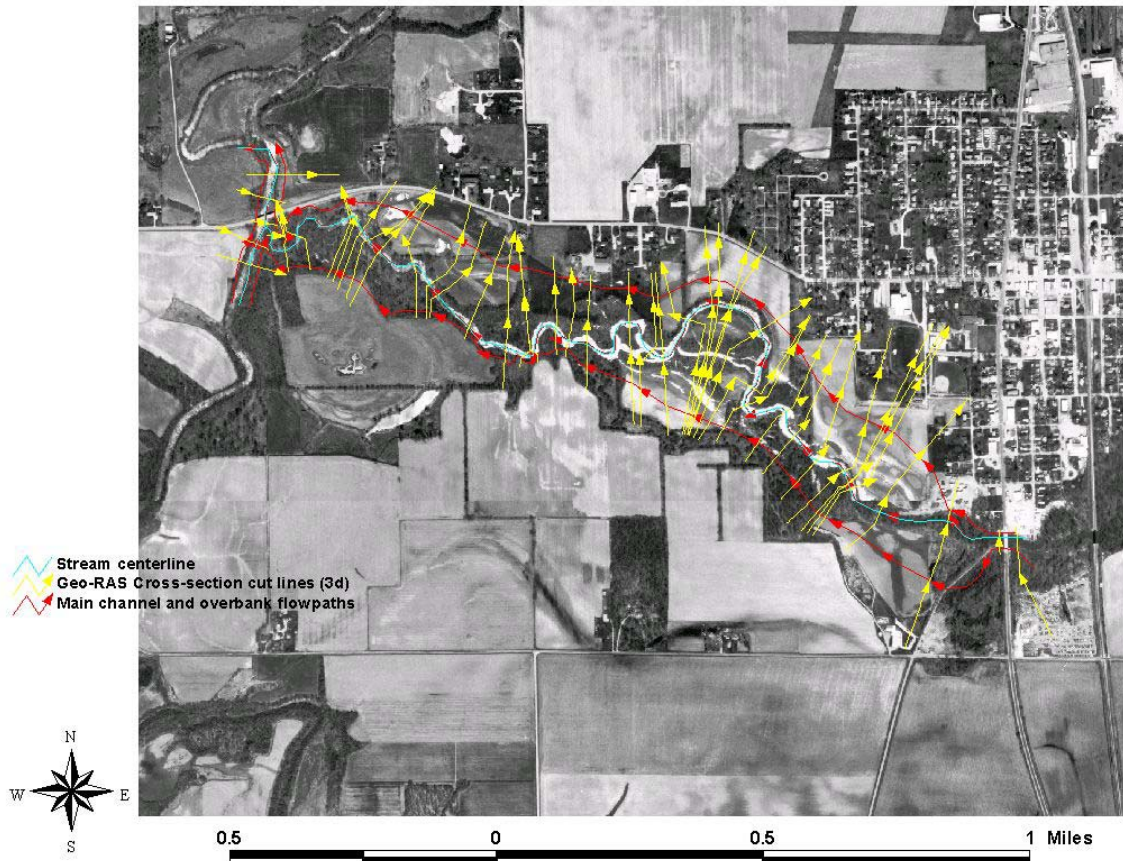
Figure 6. Sugar Creek orthophoto showing stream centerline, Geo-RAS cross-section cut lines, and main channel and overbank flowpaths used in Geo-RAS extension to generate HEC-RAS import file.
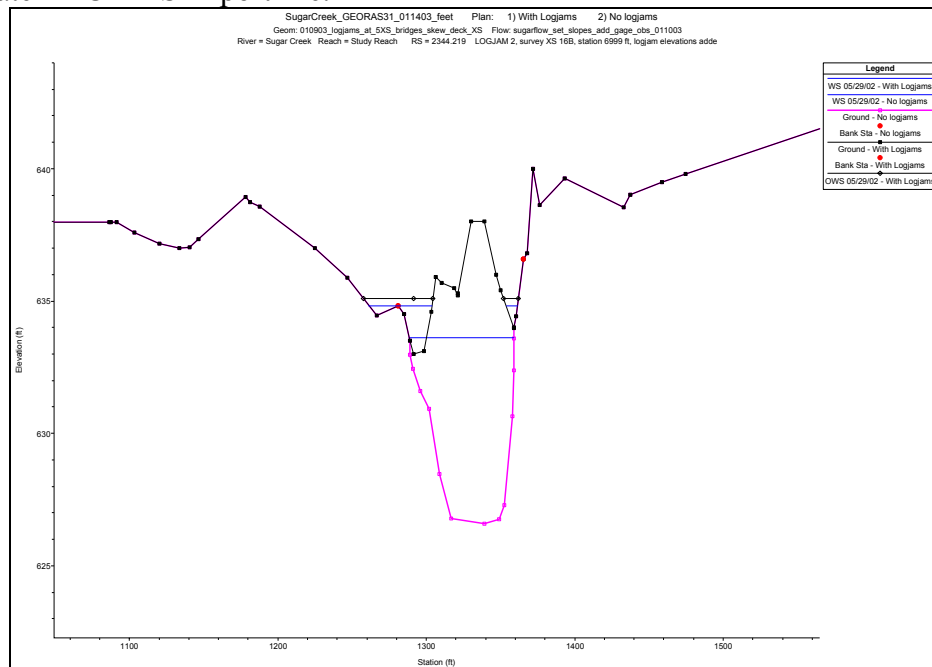

Figure 7. Sugar Creek cross-section example showing the station and elevations for geometries "With logjams" (black) and "Without logjams" (pink).
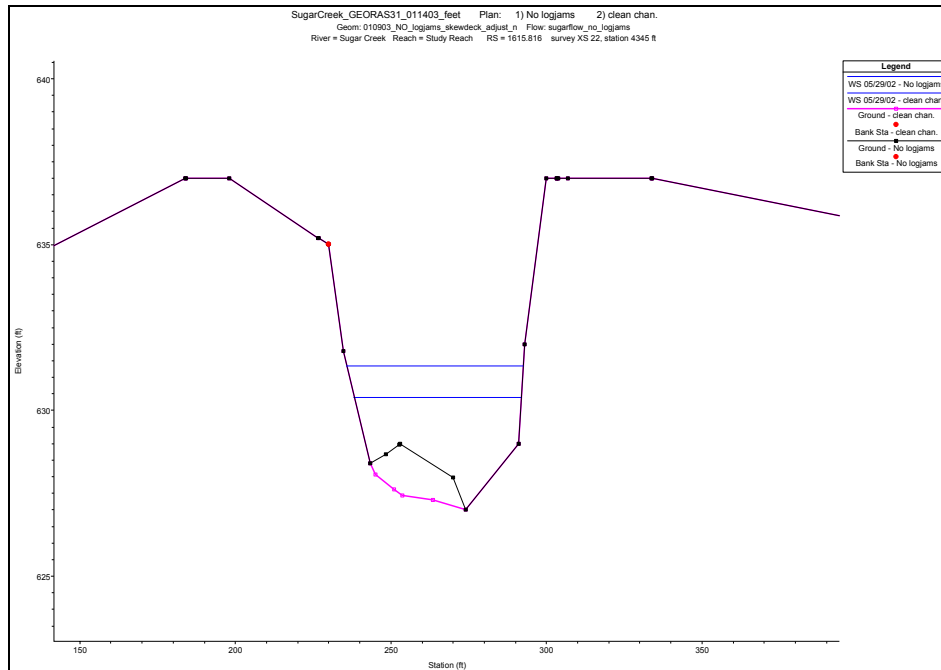
Figure 8. Sugar Creek cross-section example showing the station and elevations for geometries "Without logjams" (black) and "Clean channel" (pink).
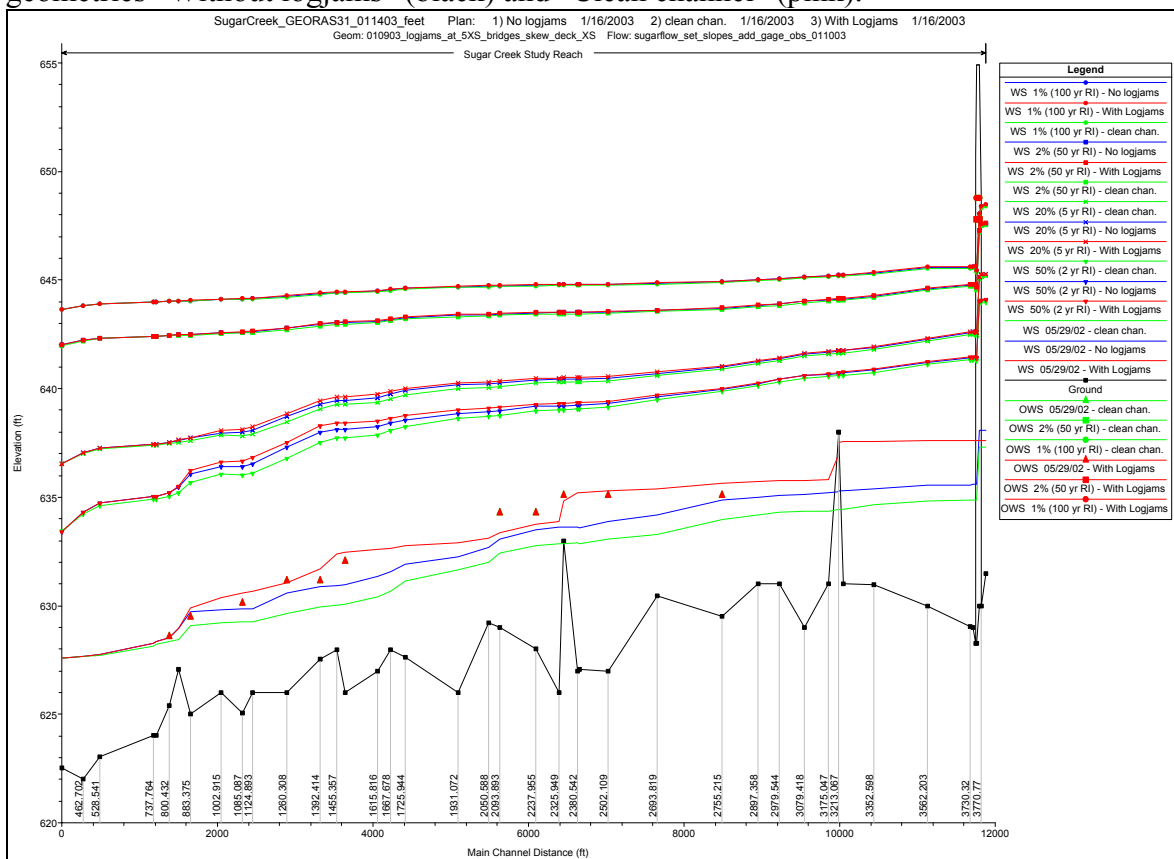

Figure 9. Water surface profiles for the Sugar Creek: 05/29/02, 2-year, 5-year, 50-year, and 100-year recurrence interval storms; showing three different geometries: With logjams (red), Without logjams (blue) and Clean channel (green).
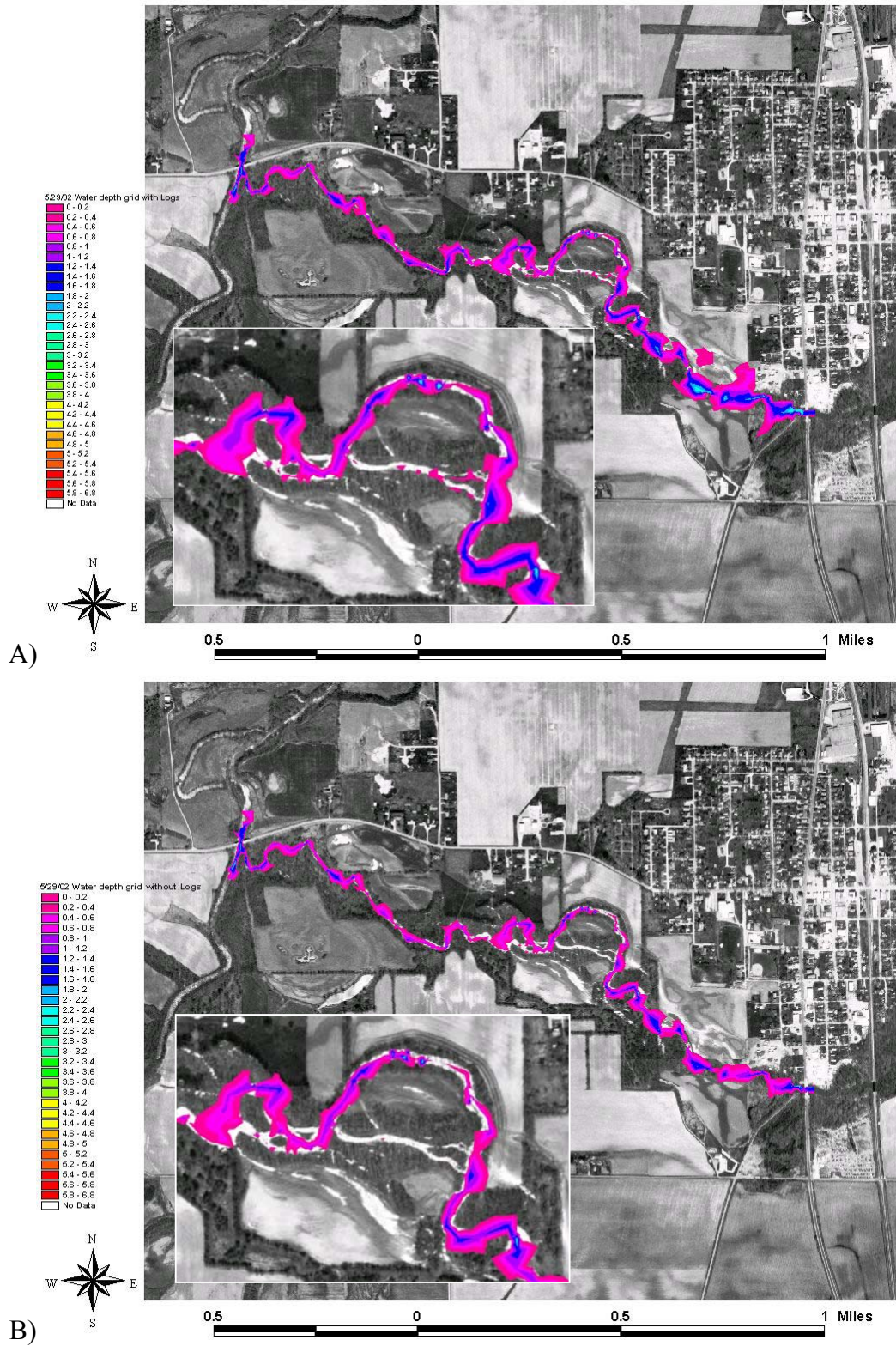
Figure 10. Sugar Creek showing the water depth for the 05/29/02 event with insets of the large cutoff region (water depth in meters): A) With logjams and B) Without logjams.